

## **ARM Progress Report (Year 2000)**

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### **2. Title of Research Grant:**

“Development of Accurate Forcing Data in Support of Single-Column Modeling in ARM”

### **3. Scientific Goal of Research Grant:**

(i) To develop and improve a variational analysis system that integrates ARM measurements from several platforms and produces improved vertical velocity, advective tendencies of temperature and water vapor, and other diagnostics, at the ARM testbeds as forcing data of single-column models and cloud resolving models. (ii) to use the analyzed ARM data for understanding cloud-related processes and evaluating GCM physical parameterizations.

### **4. Accomplishments**

- Developed a variational analysis approach that integrates several ARM measurements into an internally consistent data product for the SCM/CRM modeling community.
- Produced variational analysis products for seven ARM SCM IOPs.
- Used ARM data to raise the issue of convection triggering condition in cumulus convection parameterizations.

### **5. Progress in the last 12 months**

- The variational analysis packaged was improved in many aspects after the October ARM SCM/GEWEX GCSS4 meeting in GFDL, and it was frozen and released in January 2000. Revisions include use of additional surface observational data (e.g., radar rainfall, ECOR measurements) in the variational analysis and improved

algorithms (e.g., hydrostatic re-balancing and diagnostic methods of vertical and horizontal advections of dry static energy).

- We have produced, in collaboration with LLNL, variational analysis products for six ARM SCM IOPs in addition to the July 1995 IOP. These are IOPs that occurred during July 1997, September 1997, May 1998, January 1999, March 1999, and July 1999. These integrated data products are packaged to be self-complete with input and output information and are made easily available to the end users of the parameterization community.
- In response to issues raised at the ARM/GCSS Case 3 Workshop at GFDL, we have studied potential error sources in the lateral forcing data for the July 1997 ARM IOP, and we are actively exploring methods to reduce and assess these sources.
- We have used the variational analysis of ARM data to evaluate the NCAR SCM physics and raised the issue of convection triggering condition in the model parameterization. Namely, the model parameterization triggers convection too often in the daytime when the convective instability is large, while in observation, convection occurs when the large-scale dynamical condition is in favor. This issue of convection triggering condition will likely receive more attention in future model development efforts and observational initiatives because it has been found crucial in affecting the transient behavior of GCMs by several investigators as reported at the recent NCAR CSSM Workshop.

## 6. Appropriate Figures

**Figure 1** shows the impact of using additional ARM surface and TOA measurements as constraints on the analysis of pressure vertical velocity ( $\omega$ , mb hr<sup>-1</sup>) at the ARM SGP during the July 1995 SCM IOP.

(a) to (c) shows Barnes analysis without constraints. From (a) to (b), the subjectively selected length scale in the Barnes scheme is increased. From (b) to (c), the number of iteration in the Barnes scheme is increased. Note that the analyzed pressure vertical velocity is very sensitive to the choice of parameters in objective analyses.

(d) to (f) shows the constrained variational analysis, using the same Barnes scheme corresponding to those used in (a) to (c), with the additional use of surface and TOA measurements. Note that the sensitivity of the analyzed field to the subjective choice of

scheme parameters is significantly reduced. Furthermore, the analyzed upward motion (blue) and downward motion (down) are consistent with observed precipitation and atmospheric drying as shown in Figure 2(b) and Figure 2(c). They are also consistent with the observed energy budget at the surface and TOA.

**Figure 2** shows the time-pressure evolution of temperature (a), water vapor mixing ratio (b), and surface precipitation (c), along with the constrained variational analysis of pressure vertical velocity (d) that is consistent with each other. The period is from July 18 to August 4 and the domain is the ARM SGP.

## 7. Refereed Publications

**Zhang, M. H.**, J. L. Lin, R. T. Cederwall, J. J. Yio, and S. C. Xie, 2000: Objective analysis of the ARM IOP data: method and sensitivity. *Mon. Wea. Rev.* accepted.

Ghan et al., and **M. H. Zhang**, 2000: An intercomparison of single-column model simulations of summertime midlatitude continental convection. *J. Geophys. Res.*, 105, D2, 2091-2124.

Xie, S. C., and **M. H. Zhang**, 2000: Analysis of the convection triggering condition in the NCAR CCM using ARM measurements. *J. Geophys. Res.*, 105, D8

Cess, R. D., **M. H. Zhang**, B. A. Willicki, D. F. young, X. L. Zhou, and Y. nikitenko, 2000: the influence of the 1998 El nino upon cloud radiative forcing over the Pacific warm pool. *J. Climate*, revised manuscript submitted.

## 8. Extended Abstracts

**Zhang, M. H.**, R. T. Cederwall, S. C. Xie, J. J. Yio, 2000: Status of the variational objective analysis for ARM IOPs: update and new challenges. Proceedings of the Tenth ARM Science Team Meeting, San Antonio, Texas.

Cess, R. D., **M. H. Zhang**, X. L. Zhou, and Y. Nititenko, 2000: El Nino impacts upon cloud radiative forcing over the Pacific warm pool. Proceedings of the Tenth ARM Science Team Meeting, San Antonio, Texas.

Ghan, S., U. Lohmann, **M. H. Zhang**, 2000: Use of ARM measurements to evaluate droplet number prediction in single-column models. Proceedings of the Tenth ARM Science Team Meeting, San Antonio, Texas.

Xu, K. M., et al., and **M. H. Zhang**, 2000: Cloud-resolving model intercomparison with the ARM July IOP data. Proceedings of the Tenth ARM Science Team Meeting, San Antonio, Texas.

Xu, K. M., D. A. Randall, and **M. H. Zhang**, 2000: Evaluation of improvements of variational analyses with a cloud resolving model. Proceedings of the Tenth ARM Science Team Meeting, San Antonio, Texas.

Cederwall, R. T., et al., and **M. H. Zhang**, 2000: The ARM-GCSS and CRM intercomparison: preliminary SCM results. Proceedings of the Tenth ARM Science Team Meeting, San Antonio, Texas.

## **9. Publication Update**

The Ghan et al. paper has been published. So has the Xie and Zhang paper.

## **10. Future Work**

Research in the next year will focus on two aspects:

- (1) continue to improve the variational analysis of ARM data, including the exploratory use of remotely sensed data and variational analysis of TWP and NSA products.
- (2) use ARM data to understand the underlying physical processes of the parameterization targets.

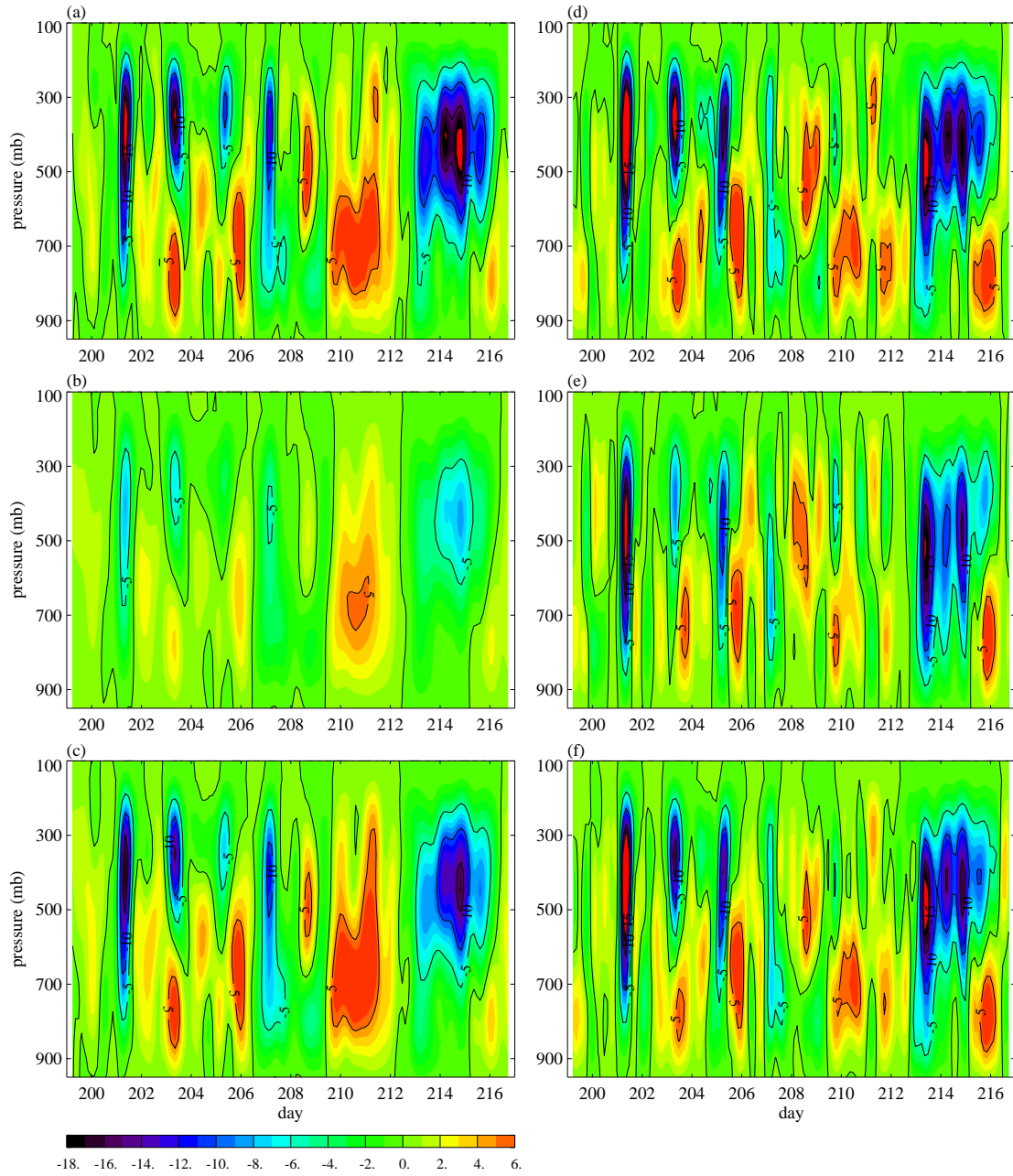


Figure 1. Pressure Vertical Velocity  $\omega$  (mb/hour)

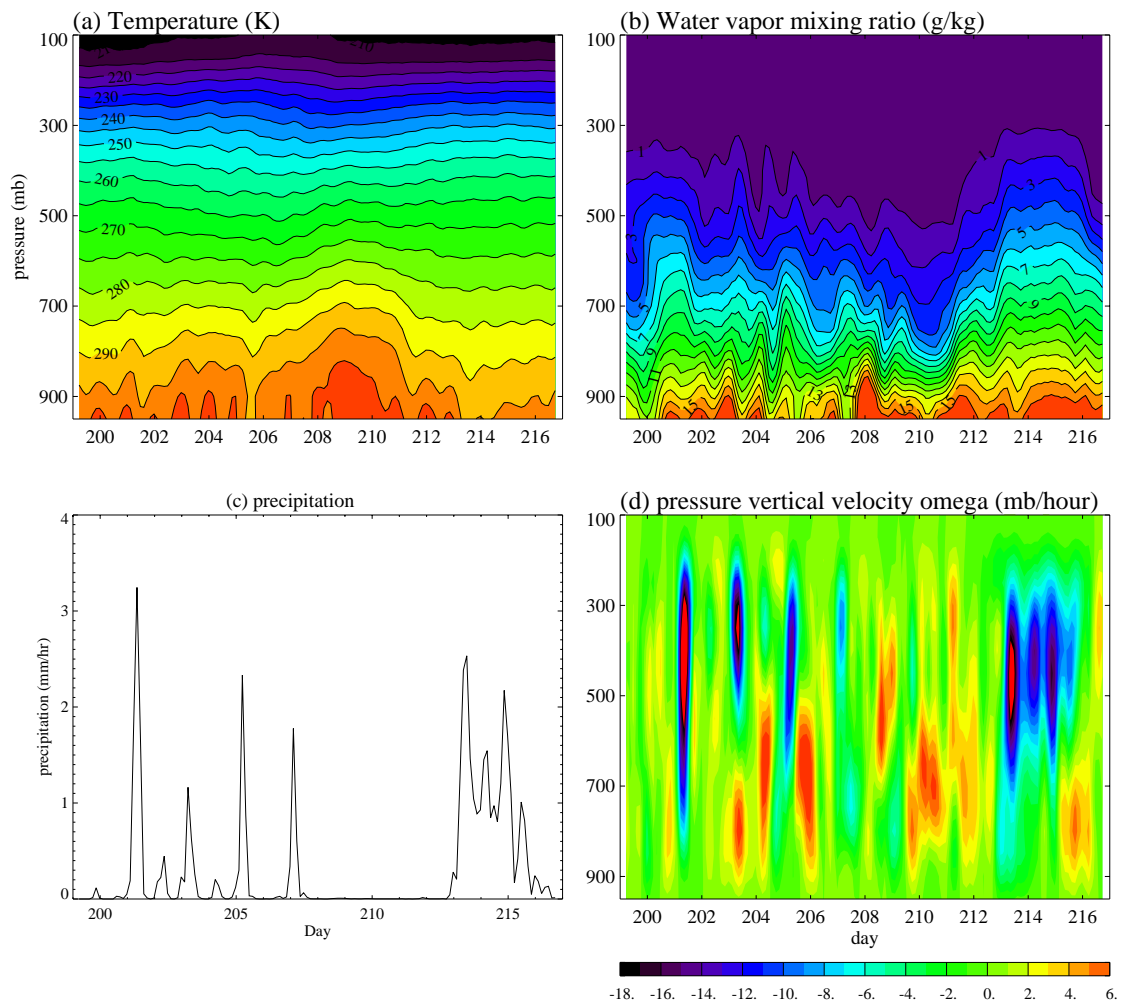


Figure 2. July 1995 ARM IOP at the SGP.